Price-Performance Model: Household Water Treatment and Safe Storage Devices

Critical opportunities for product improvement

Background

Safe drinking water is essential to good health. However, in resource-poor settings, water often comes from unsafe sources and carries deadly pathogens. The World Health Organization estimates that 1.8 million people die each year from diarrheal diseases, many of which are attributed to unsafe water. Safe drinking water is one of the United Nation's Millennium Development Goals—by 2015, the United Nations hopes to decrease the proportion of people without sustainable access to safe drinking water by 50 percent.

To increase access to clean water, PATH's Safe Water Project is exploring the potential for commercial enterprises to target low-income populations with household water treatment and safe storage (HWTS) consumer products. We are working to identify, adapt, and develop appropriate HWTS products and business models with a goal of catalyzing market-based forces to take on production, distribution, sales, and maintenance of products for low-income households.

Commercial markets offer growth potential and are a viable model for sustainably providing safe water to these populations. This has been demonstrated in recent years through private-sector marketing mechanisms, industrial capacity, and sales-and-service networks for many consumer-based products in developing countries. Product examples include fast-moving consumer goods such as shampoo and laundry detergent, and durable goods such as cell phones and solar lighting.

The Safe Water Project team is promoting changes within the HWTS product category to benefit low-income populations. We do this by offering to commercial partners a clearer understanding of the HWTS market and low-income user needs, with the understanding that this information can guide decisions about where to focus efforts to increase end-user satisfaction. Increased satisfaction leads to greater perceived value and greater likelihood of purchase, as well as consistent, proper use. In other words, we are sharing the analysis presented here to help commercial partners focus on product attributes that are both easy to improve and likely to improve consumer perceptions.

Introduction to price-performance concepts

A major driver for innovation in product development is understanding what consumers perceive to be the product value in relation to the amount of money spent. Take, for example, a consumer in a store comparing products. The person holds one product in each hand and has an eye on a third, shelved product. By reading the packaging and asking questions of the nearby salesperson, the person tries to imagine using each product in its context. Some questions consumers might naturally ask themselves are:

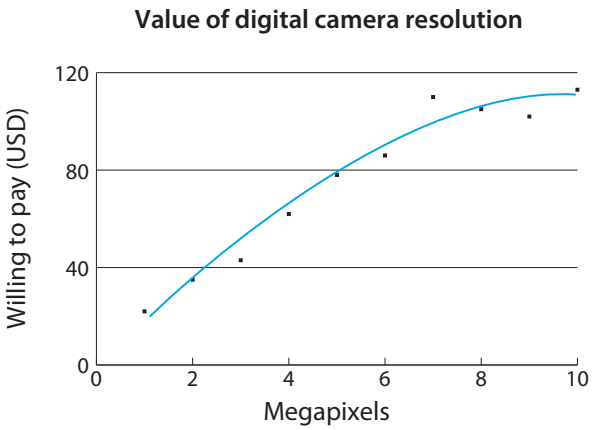
"I like that feature, but do I really want to spend $20 more to get it?"

"I wonder why this one is so much less expensive… is there something wrong with it?"

"I can afford the expensive one and I like it, but do I need it?"

Many tools, such as conjoint analysis (a statistical technique to determine how people value different features that make up an individual product or service), can be used to uncover consumers' preferences and price sensitivities. These tools yield data similar to those shown in Figure 1, which presents an example of a "traditional" price/performance relationship (not real data).

Figure 1. An example of traditional price/performance relationship (not real data).



Gathering and generating data like that in Figure 1, however, requires consumers who are highly engaged in the product category. A market researcher trying to come up with this conjoint analysis would probably screen for participants who have some knowledge of the product—such as those currently shopping for a digital camera or those who recently purchased one. The researcher might screen out potential participants who cannot define key terms about digital cameras.

Special considerations for submerged markets

Unlike consumers who are highly engaged in a product category, potential HWTS consumers in the submerged market[1] that we are trying to serve are often unable to make price/feature or price/performance comparisons. Reasons include:

- Generally, they do not have experience with similar products in the HWTS category. This makes it very difficult for them to give feedback on their preferences for product concepts or features.
- Generally, they do not have much choice in the marketplace. For example, given the low market penetration of HWTS devices, consumers typically have one or no purchasable devices available at nearby sales locations.
- There are competing needs for the relatively large amount of money necessary for the purchase of HWTS products. Consumers are not weighing feature tradeoffs but are considering what category of product they need most, weighing HWTS devices against refrigerators, bicycles, televisions, radios, and other major purchases.

These population characteristics make it very difficult to uncover reliable correlations between particular product features and prices. Imagine how difficult it would be for someone who had never seen or used a camera to give feedback about particular features such as resolution and shutter speed. We have found it more fruitful to watch participants engage with functional or semifunctional prototypes rather than try to engage them in conversation about hypothetical needs and wants. If we are not careful about how we conduct research on consumer needs and preferences, we get responses that are not useful, such as:

"That all looks good."

"I like it… Why?... I do not know. I just do."

PATH's Safe Water Project has used an alternative approach, outlined below, to collect data on user preferences and values among consumers in the submerged market. The results can be applied to improve existing HWTS products or develop new products.

[1] "Submerged market" describes families living on less than US$5 per person per day. This market segment is also called the base of the pyramid, or BoP.

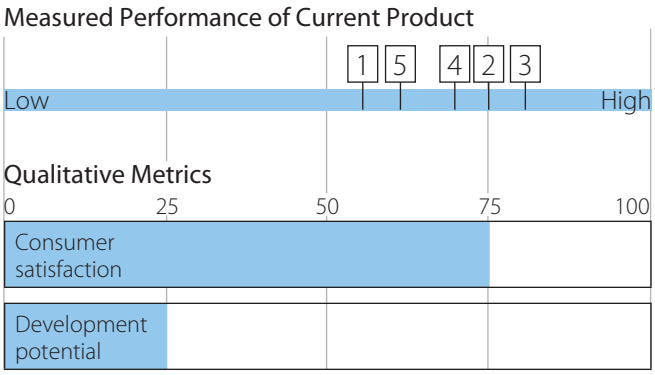
An alternative approach to collecting data on user preferences

The following analysis focuses on the submerged market in India where awareness and use of HWTS devices is incredibly low. Only 6% of the market use a filtration device (other than cloth or plastic sieves), and 61% never treat water.

Continued product development is critical to growing the market for consumer HWTS products and better meeting household needs for safe water. Product developers must find creative ways to improve function and design with minimal consumer input.

To address this challenge, PATH's Safe Water Project developed a way to visualize data, to illustrate the importance of improving various generic attributes of HWTS devices. Two examples follow; one is for a product attribute that does not warrant prodcut development attention, and one is for a product attribute that does.

Product attribute X – does not warrant development attention

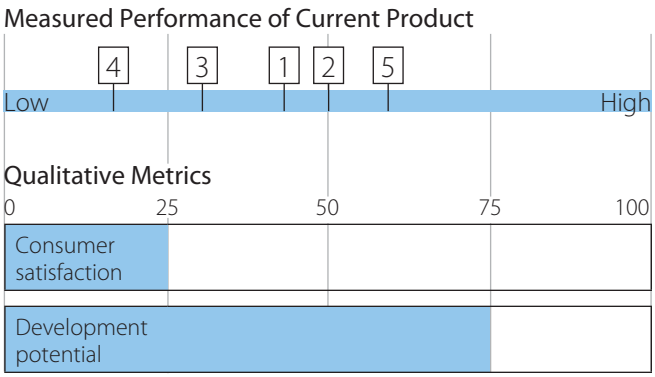


The data display for product attribute X shows three things:

1. The measured performance of a particular attribute for five commercially available (in this example, pretend) products.
2. Consumer satisfaction with the range of performance represented by the five products, with 0 being not at all satisfied and 100 being extremely satisfied.
3. The amount of development potential for the attribute.

The measured performance bar shows that the five products all perform relatively well and score close to each other. The qualitative metrics graphic shows that consumer satisfaction is high for the range of performance exhibited by the five products and that there is little development potential. Development potential is meant to reflect how easy or inexpensive it is to make improvements to the attribute. Low development potential means that improvements to performance for the measured attribute are difficult or costly. In this example, the existing products perform well (are mature), improvements are difficult or costly, and consumers are not likely to evaluate the attribute more favorably even if improvements could be made.

Product attribute Y – warrants development attention



The data display for attribute Y, by contrast, conveys that the existing products perform poorly, consumers are generally dissatisfied with that range of performance, and it would be easy or inexpensive to improve the attribute. This is exactly where to spend effort developing a product.

On the following pages, this model for displaying data is applied to many different attributes of HWTS devices. To do this, the project team first listed the general attributes or characteristics of HWTS devices (see Appendix). We then prepared descriptions of five commercial devices available for purchase in the target regions of India as well a PATH prototype product that shows how we would improve performance. All functional units have been field tested. The project team then applied the model to all of the attributes. Finally, we identified the nine most promising areas for innovation. Listed in order from highest to lowest in terms of where we recommend investing in product development, these areas are:

- Initial purchase price
- Filter life
- Ease of setup and first use
- Dispensing mechanism
- Tap height placement
- Filling experience
- Availability of filter options to treat a range of contaminants
- Indicating filter end-of-life
- Treatment efficacy

Overview of devices

In this analysis, the cost per liter is amortized over five years for a family of five with a consumption rate of 4 liters/person/day (safety factor of two for minimum daily requirement of 2 liters/person/day). The currency conversion rate was Rs45 per US dollar, reflecting the rate on May 14, 2010.

Aquasure (AS)

Manufacturer:	Eureka Forbes Ltd.
Technology type:	Mechanical filtration with contact chemical disinfectant
Treated water cost per liter:	$0.0041 (purchase price, $45 [though the Eureka Forbes website lists a similar model at $31, PATH has not confirmed availability]).
Batch volume:	13 liters to fill top chamber
Flow rate:	Approximately one hour to drain top chamber
Service life:	1,800 liters per cartridge
Filter replacement cost:	$8.87
Safe storage:	Included
Efficacy:	99.54% reduction of bacteria; 98.05% reduction of virus; 99.84% reduction of protozoa.[2]
Maintenance:	Clean top and bottom chambers periodically. Clean pre-filter and cartridge fabric filter as needed to remedy reduced flow. Back-flush top mechanical filtration cartridge as needed to maintain flow. Replace complete filtration cartridge assembly at end of service life.

Ceramic water purifier (CWP)

Manufacturer:	Various (International Development Enterprises, Rural Development Institute, local manufacturers)
Technology type:	Ceramic filter, impregnated with colloidal silver (bactericidal agent)
Treated water cost per liter:	$0.0008 (purchase price, ~$15)
Batch volume:	13 liters to fill top chamber
Flow rate:	Approximately 13 liters per hour
Service life:	Recommended pot replacement every one to two years
Safe storage:	Included
Efficacy:	94% to 98% reduction of bacteria.[3] No current independent test data available for viruses or protozoa.
Maintenance:	Clean ceramic filter as needed (mean reported frequency = 1.3 times per week). Manufacturers recommend replacing the clay pot every one to two years, but research suggests that filters can remain effective for up to four years in regular use.[3]

* The Eureka Forbes website lists a similar model at $31, but we have not confirmed availability.

[2] Clasen, Menon. Microbiological performance of common water treatment devices for household use in India. International Journal of Environmental Health and Research. April 2007: 17(2): 83–93.

[3] Brown J, Sobsey M, Proum S, et al. Use of Ceramic Water Filters in Cambodia. August 2007. Water and Sanitation Program (WSP), UNICEF. (www.wsp.org). The photo is also from this publication.

PATH design example (P)

Manufacturer:	Commercial partner TBD
Technology type:	TBD
Treated water cost per liter:	TBD
Batch volume:	10.15 liters to fill top chamber
Flow rate:	TBD, specified at least 4.8 liters per hour
Service life:	TBD
Safe storage:	Included
Efficacy:	TBD
Maintenance:	TBD

PureIt (PI)

Manufacturer:	Hindustan Unilever, Ltd.
Technology type:	Mechanical filtration with contact chemical disinfectant and activated carbon
Treated water cost per liter:	$0.0055 (purchase price, $44)
Batch volume:	13 liters to fill top chamber, 9 liters treated water capacity
Flow rate:	Approximately 13 liters per hour
Service life:	1,500 liters (filter replacement cost, $8.11)
Filter replacement cost:	$8.87
Safe storage:	Included
Efficacy:	>99.9999% reduction in bacteria; >99.99999% reduction in viruses; >99.9% reduction in protozoa in laboratory tests[3]
Maintenance:	Clean filters (two) and back-flush carbon block as needed to improve flow. Replace filter components at end of service life as indicated by flow stop and visual indication.

Rama, 3 candle version (RA)

Manufacturer:	Rama (many similar designs by OK, Butterfly, etc.)
Technology type:	Ceramic candle filter
Treated water cost per liter:	$0.0026 (purchase price, $33)
Batch volume:	10 liters to fill top chamber (varies by manufacturer)
Flow rate:	1 liter per hour per filter candle (up to 4)
Service life:	6 to 12 months per candle (filter replacement cost for three candles, $4)
Safe Storage:	Included
Efficacy:	Butterfly ceramic filter pots demonstrated: >99.99% reduction of bacteria; 98.30% reduction of virus; 99.74% reduction of protozoa[3]
Maintenance:	Clean ceramic filters to improve flow rate.

Swach (SW)

Manufacturer:	Tata Chemicals, Ltd.
Technology type:	Mechanical filtration with adsorption and silver disinfection (rice husk ash and silver)
Treated water cost per liter:	$0.0031 (purchase price, $22)
Batch volume:	9 liters to fill top chamber
Flow rate:	Approximately 3 liters per hour
Service life:	3,000 liters (filter replacement cost, $6.64)
Safe storage:	Included
Efficacy:	No current independent test data available.
Maintenance:	Clean the three pre-filters weekly. Replace pre-filters and filter at end of service life or after six months.

Product attribute analysis

The following analysis is intended to help clarify key areas for improvement of the products within the HWTS category. The data and conclusions are based on PATH's cumulative experience with consumers in the submerged market and specific research to understand user needs for HWTS devices in India. These data include:

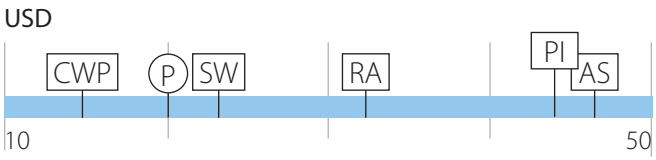
- Contextual inquiry and interviews with 270+ households.
- Quantitative surveys of 2,400+ participants.
- Water quality testing in 500 households.
- Ongoing distribution and marketing pilots with 2,200+ participants in Andhra Pradesh, Uttar Pradesh, Madhya Pradesh, and Tamil Nadu.

Where quantifiable, we have given exact measurements of the devices, and the qualitative measures are our considered synthesis based on data collected. We intentionally kept qualitative evaluations broad and not overly precise in recognition of the nature of the data we have collected. Respecting these limitations of qualitative data, we show satisfaction and development potential in quartile increments. The conclusions are most relevant to products meant to be distributed in these same regions.

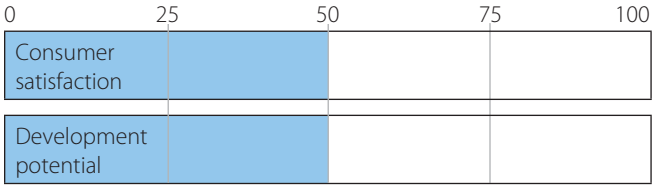
The data displays for key product attributes use the following abbreviations:

Product	Abbreviation
Aquasure	AS
Ceramic water purifier	CWP
PATH design example	P
PureIt	PI
Rama	RA
Swach	SW

Initial purchase price



Qualitative Metrics



Data (presented in US Dollars as of May 14, 2010, conversion rate—Rs45 per USD)

Aquasure: $45

Ceramic water purifier: Est. $15

PATH design example: Target $20

PureIt: $44

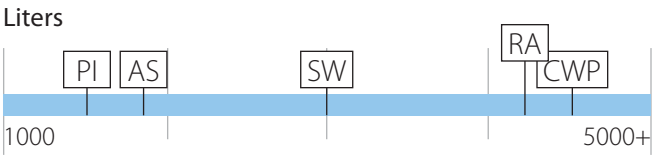
Rama: $33

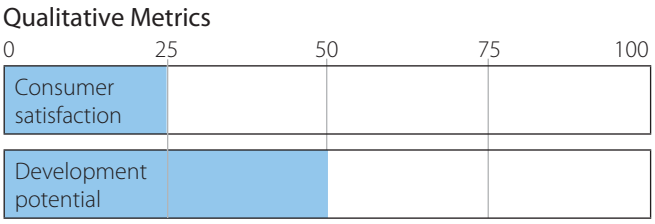
Swach: $22

Given that there are reasonably affordable options in the market, satisfaction is moderate because consumers can see that they have plausible choices. The consumers surveyed reported $20 as an affordable price point with available financing plans.

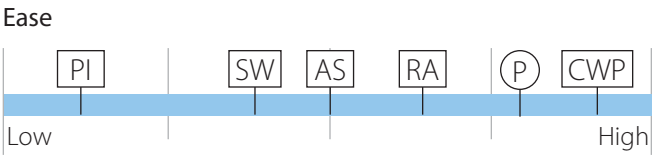
The development potential is moderate because there is room to develop new products at $20, but achieving a lower price point will remain a challenge. With an assumption that plastic and stainless steel prices will stay relatively constant, the main area of focus will be development of new, less-expensive treatment technologies. Because lower-cost HWTS devices will enable far greater market penetration, cost-reduction efforts deserve attention.

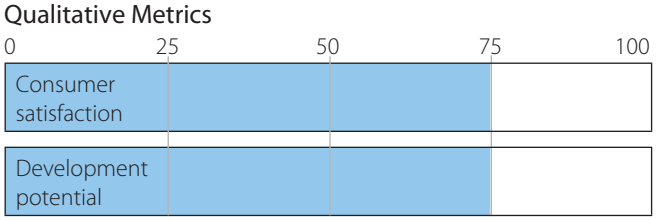
Filter life





Setup and first use





Data (manufacturers' claims or recommendations)

Aquasure:	1800 liters (3.5 months, on average)
Ceramic water purifier:	Manufacturers recommend replacing clay pot every one to two years
PATH design example:	TBD—recommending a minimum of six months
PureIt:	1,500 liters (three months, on average)
Rama:	Manufacturers recommend replacing ceramic candles every 6 to 12 months.
Swach:	3,000 liters (six months, on average)

The combination of a durable product (the housing of the device or containers) with a consumable product (a filter that must be replaced periodically) is a challenge to the consumer's perception in the submerged market of what a durable product should be. The consumers surveyed typically expected the filter to last as long as the housing (two to three years). They begrudgingly acknowledged that filters eventually wear out. Most consumers said $8 spent every five to six months was an acceptable price.

The development potential is moderate because ceramic filters already have an acceptably long life. A substantial improvement in filter life has the potential to increase satisfaction.

Data

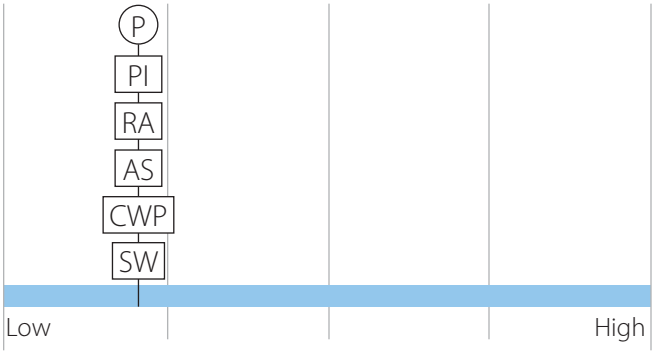
Aquasure:	Relatively few parts that assemble easily; necessary back-flush tool
Ceramic water purifier:	Screw in tap, soak clay pot, and place it in bucket
PATH design example:	Designed to be mechanically impossible to assemble incorrectly
PureIt:	Many parts with unclear function
Rama:	Few parts, but no indication of direction of assembly for the candles or sealing washers
Swach:	Small, difficult-to-see filter retention features; otherwise straightforward

Even if the devices are difficult to assemble, it is generally possible to assemble them correctly with minimal assistance. Once a consumer learns the process, repeated assembly is straightforward. This makes for moderately high satisfaction. Because it is easy to reduce part counts and decrease the likelihood of incorrect assembly, the development potential is also moderately high.

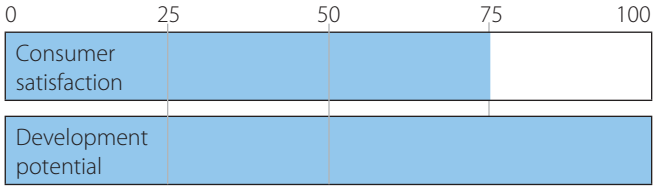
The submerged market has little or no exposure to HWTS devices, so cues for correct assembly are not always understood as expected (e.g., matching a seal to a similarly sized feature). Participants in PATH's usability studies tend to try different ways to assemble the device until there are no parts left and it looks reasonably "together." From these studies, PATH has learned that using colors or obvious shape matches helps to make assembly clearer and easier. Also, the more complicated the device, the more the device makes users feel incompetent; there is room to make assembly support a positive self-image.

Dispensing mechanism

Tap reliability



Qualitative Metrics

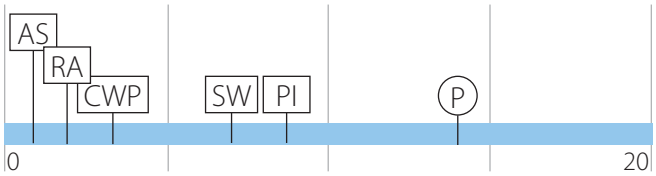


No data shown since all devices use nearly the same tap with similar failure modes

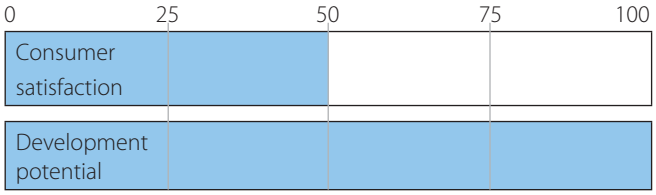
Taps on all these devices tend to fail (leak or break) well before the product itself is worn out. This observation, taken on its own, would suggest that satisfaction is quite low, but replacement taps are readily available and fairly easy to install. Although dripping taps make wet spots on the floor, the households in the submerged market often exhibit and seem to tolerate far more disarray in other forms. Development potential is at a maximum since the off-the-shelf taps we have encountered all seem equally fragile in various ways; no tap choice is substantially better than any other, yet plastic taps in other applications perform reliably. Although the PATH design example includes an inexpensive and easy-to-replace tap similar to all of the others in this category, a novel, easy-to-use, durable, and inexpensive tap has the potential to elevate user experience.

Tap height placement

cm from bottom of device



Qualitative Metrics

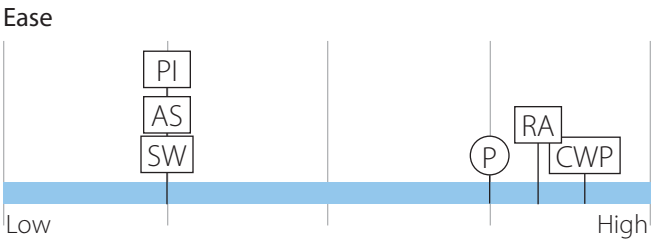


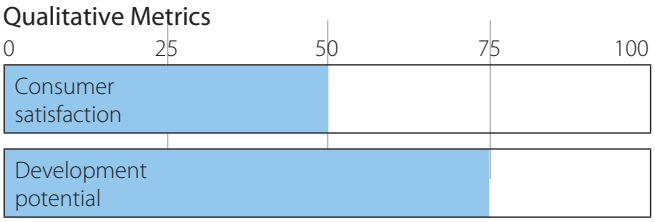
Data (manufacturers' claims or recommendations)

Aquasure:	0.6 cm
Ceramic water purifier:	2 cm
PATH design example:	13.5 cm
PureIt:	7.8 cm
Rama:	1 cm
Swach:	6.7 cm

Consumers prefer using an HWTS device such that the tap can dispense water easily into another container. Research shows that it is acceptable to place devices with low taps on the edge of a counter or similar elevated surface but also that stands are a valuable product feature. A stand should make it easy to fill a container of standard height (an Indian 1-L "lota" is ~13 cm tall). A stand also conveys a visual sense of stability and gives users more room for food preparation because the device can be pushed to the back of the counter. There is maximum development potential because a stand is easily designed and included with the original purchase or sold as an accessory.

Filling expericence





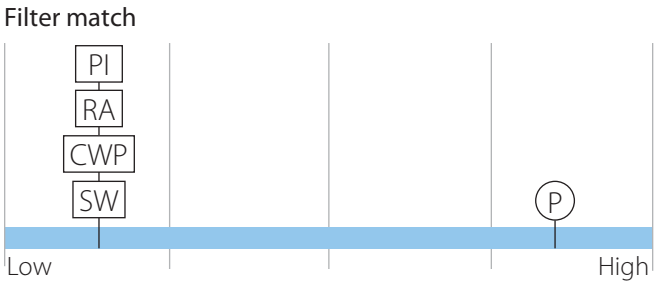
Data

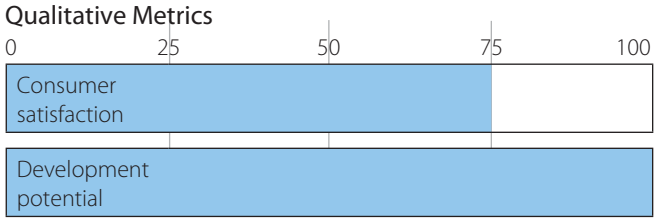
Aquasure:	Small, easily clogged pre-filter
Ceramic water purifier:	No pre-filter, possible to fill the entire volume as quickly as desired
PATH design example:	Large, course pre-filter with little flow restriction
PureIt:	Small, easily clogged pre-filter
Rama:	No pre-filter, possible to fill the entire volume as quickly as desired
Swach:	Small, easily clogged pre-filter

Any current product with a pre-filter becomes slower to fill as the pre-filter clogs with particles from untreated water, or if the pre-filter dries out completely and needs to be rewetted. When this happens, users must fill the pre-filter and then wait for it to drain into the upper container, repeating this process many times until the upper container is full, making for a moderately satisfying experience. As with taps, existing pre-filters are practically identical, and alternative approaches need to be explored. Ease of filling is also determined by the overall height of the device, but since all of the devices are within an acceptable height range, this attribute is more about flow restriction from the pre-filter.

The Rama and ceramic water purifier have no pre-filters, and the latter has the added advantage that it will not overflow unless the user pours water over the device's top rim. The PATH design includes a large-capacity pre-filter that will have a minimum effect on flow rate. An effective, easy-to-clean, high-flow pre-filter can increase consumer satisfaction.

Availability of filter options to treat a range of contaminants





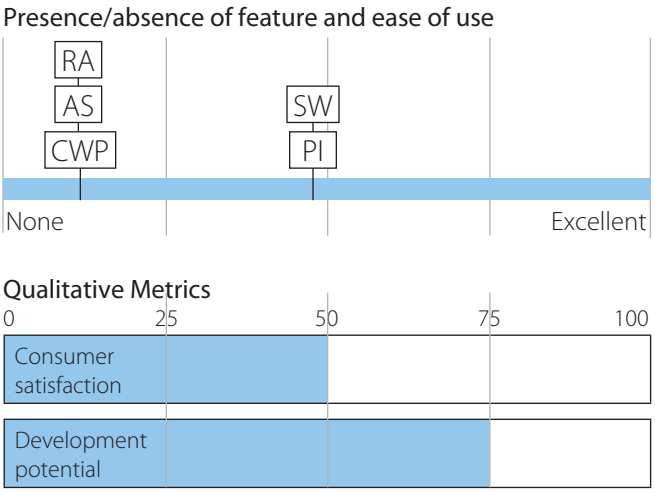
Data

Aquasure:	None
Ceramic water purifier:	None
PATH design example:	Recommending a standard interface to allow filter interchangeability
PureIt:	None
Rama:	None
Swach:	None

Because filters that remove specific contaminants are not available in the Indian marketplace, consumers do not envision HWTS devices with the ability to treat specific contaminants. Conversely, research subjects sometimes express concern about whether a particular HWTS device treats a local contaminant of concern (e.g., fluoride or arsenic). We have rated satisfaction relatively high since most consumers do not expect this feature, and we have put development potential at maximum since the technology is available but no products are currently available.

Each HWTS device has a proprietary interface and can connect to only one filter (excluding counterfeit products, if any). The PATH design includes a standard filter interface which makes it possible to switch filters without having to switch the entire device. A single filter manufacturer could develop a line of compatible filters, and multiple manufacturers could design both containers and filters to be compatible. This approach has the potential to increase consumer interest by offering choices among various filters that would be compatible with their devices.

Filter end of life indication

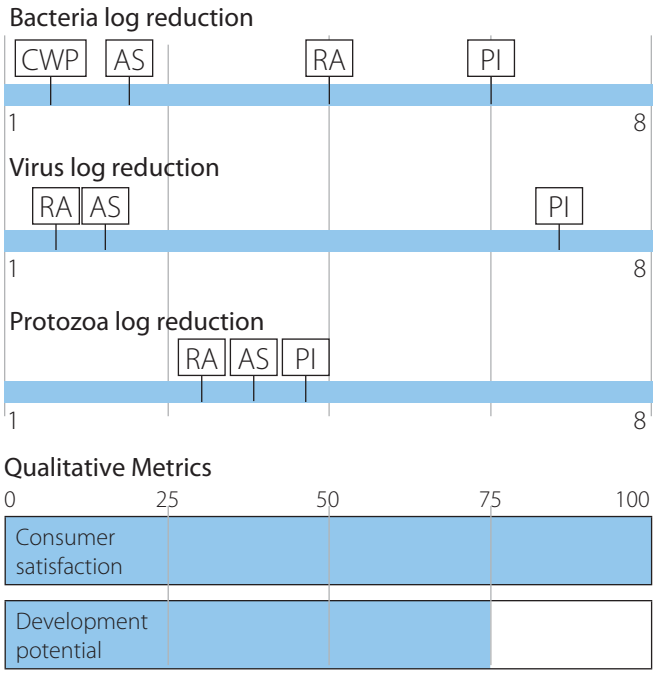


Data

Aquasure:	None
Ceramic water purifier:	None
PATH design example:	TBD, recommending slowing down flow rate and visual indication
PureIt:	Flow shutoff and visual indicator
Rama:	None
Swach:	Flow shutoff and visual indicator

Indicators are either absent, difficult to read and interpret, or designed to completely shut down the device, so satisfaction should be quite low. Because consumers do not consider this feature particularly important, satisfaction is moderate and difficult to change. Although this looks like an attribute that should be given little attention, it is included here to give some visibility to PATH's recommendation that any end-of-life indicator should slow flow before or instead of blocking it (in addition to a visual indicator). The concern is that if the device stops working altogether and a replacement filter is not immediately available, users will return to drinking untreated water out of potentially unsafe storage vessels. The development potential is moderately high because there seem to be no barriers to implementing this recommendation. The PATH design is not shown in the data display because specifics about filter performance (including the end-of-life indicator) are meant to be determined by the individual manufacturer.

Treatment efficacy



Data (log-reduction values for bacteria, virus, and protozoa)

Aquasure:	bacteria: 2.3; virus: 1.7; protozoa: 2.8
Ceramic water purifier:	bacteria: 1.4 (no data for virus or protozoa)
PATH design example:	bacteria: TBD; virus: TBD; protozoa: TBD
PureIt:	bacteria: 6; virus: 7; protozoa: 3
Rama:	bacteria: 4; virus: 1.8; protozoa: 2.6
Swach:	No current data. Product is being modified at this writing

Treatment efficacy is included because it comes to the foreground in many of the conversations about the price and performance of HWTS devices. PATH's research indicates that consumers do not relate to the variation in treatment efficacy; they simply assume that any device will make their water "safe." This observation, combined with the evidence that the use of safe storage devices alone produces demonstrable public health benefits,[4] leads to consideration of a tradeoff between efficacy and price. Of course, if high-efficacy water treatment is available at low cost, it should be incorporated in any device. The HWTS community should consider whether it is better to provide a less-effective device at a more-affordable price than a more-effective device at a price that would exclude more consumers. We do not know the answers to this, but we think it warrants serious attention and are involved in policy and standards discussions related to treatment efficacy.

[4] Roberts L, Chartier Y, Chartier O, et al. Keeping clean water clean in a Malawi refugee camp: a randomized intervention trial. *Bulletin of the World Health Organization*. 2001; 79: 280–287.

Conclusion

PATH relies on partners and the private sector at large to manufacture the products we help to develop, so PATH's role in the product development process consists of catalyzing, advocating, networking, researching, prototyping, and recommending. PATH hopes that this document is useful as a starting point and that the analysis is helpful to HWTS manufacturers. The best possible outcome from PATH's perspective would be for HWTS manufacturers to incorporate some of these recommendations into their products, demonstrate their value (be it positive or negative), and provide feedback so that PATH can update our recommendations.

Many of the product attributes discussed in this analysis have clear implementation pathways and do not require new technology or a novel application of existing technology. Though not necessarily simple, they are provisionally defined and ready to be implemented.

The two attributes that come to the forefront in nearly every conversation with consumers in the Indian submerged market are purchase price and filter life. These attributes will require novel solutions.

A reasonable assumption is that a commercially sustainable (profitable) product must be produced and delivered to a local distribution point for approximately half the eventual retail price. Even devices with relatively few parts (lid, pre-filter, container for untreated water, container for treated water, a stand, and a filter) are challenging to produce at or near the lowest prices of currently available devices. Cost savings are not likely to be found in the cost of the plastic to make the containers. This cost simply depends on building a container to hold a sufficient volume of treated water, multiplied by the wall thickness, multiplied by the cost of plastic. The real potential for cost savings lies in filter development.

In the PATH design example, nearly half of the production budget is allocated to the filter, and the choice of filter technologies has a large influence on that cost. If a filter could be developed with the same or similar filtration efficacy for less money, HWTS manufacturers could sell to individuals earning lower wages or could eliminate the need for consumer financing. This is naturally coupled with the need to find solutions for longer filter life.

As consistently highlighted in our interactions with Indian consumers, longer filter life for existing prices is an important but unsolved problem. Solutions would make the products more affordable to a greater portion of the market without the need for subsidy.

In the spirit of full disclosure and to promote discussion about how to make analyses like this more useful, we note several gaps that need to be filled:

1. Making product use more satisfying does not necessarily translate into products being detectably better at the point of sale. Features that sell a product and features that promote satisfying day-to-day use are not always the same thing. For example, a pre-filter that allows for a high rate of flow and a pre-filter that does not may look exactly the same at the point of sale, though the former will enable higher long-term satisfaction. As manufacturers improve performance as described in PATH's design example, we will see whether and how any of the features can be used to enhance the product image at the point of sale.
2. This analysis is based on a snapshot in time in a very new and highly dynamic product category. As soon as an HWTS manufacturer resolves one of the major issues and gets visibility in the marketplace, consumer satisfaction will increase and development potential will decline. For the first manufacturer, this represents a competitive opportunity, and those that react slowly will be left behind (assuming consumers have a choice among devices).
3. Despite the availability of a number of major branded products for sale in India, awareness and use of HWTS devices in the Indian submerged market is incredibly low. Our data show that only 6% of the market uses a filtration device (other than cloth or plastic sieves) and that 61% never treat their water at all. As soon as this starts to shift, awareness of features and brand differentiation will grow, making it possible to do the more detailed type of analysis highlighted in Figure 1.

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Appendix: Characteristics of HWTS devices

Included in this analysis

HWTS product characteristics	Definition
Purchase price	non-amortized initial expense
Filter life	time between necessary replacements of the filter
Initial setup and first use	ease of initial setup and first use
Dispensing mechanism	reliability of the dispensing tap
Tap height	measured from bottom of tap to resting surface (cm)
Filling	ease of filling the container with untreated water
Device to water source compatibility	ability to match filter to local water source
End of life indicator	communicates end of filter life
Treatment efficacy	log reduction for bacteria, virus, and protozoa

Not included in this analysis

HWTS product characteristics	Definition	Reason for exclusion
Aesthetic appeal	desirability and appropriateness of the design	design directions vary regionally and are sometimes polarizing
Assembly/disassembly	ease of assembly/disassembly	once learned, all products are within an acceptable range
Durability	ability to withstand typical use	long-term field data do not exist
Endorsements and claims	effectiveness and credibility of marketing messages	leverage credible advocates like doctors and educators
Expected life of product	how long the product will last before terminal failure	long-term field data do not exist
Footprint	2-dimensional space consumed under device	all products are within an acceptable range
Level indicator	communicates volume of water in the device	valuable feature that is easy and inexpensive to include
Localization	translation of user assistance for different regions	implement universally accepted icons or keep device simple enough that it is not needed
Overall height	measured from bottom to top of lid (cm)	all products are within an acceptable range
Packaging	utility and desirability of packaging	packaging should be small, and sequential removal should support first-time assembly
Periodic maintenance	ease of periodic maintenance	filter replacement is the only maintenance required

HWTS product characteristics	Definition	Reason for exclusion
Plastics vs. ceramics vs. metals	material choices for production	material choices may vary regionally and are sometimes polarizing
Pre-filter	course filter generally hanging above main filter	easy improvements over existing products—better flow rate, less clogging
Product format	general product architecture	consumers generally expect unpowered, gravity-fed, two-container devices
Rate of treatment	flow rate for water treatment (mL/min)	consumers want higher rates, but not at higher prices and can adapt to a broad range of rates
Residual disinfection	presence of residual disinfectant in treated water	beneficial to include to minimize recontamination of treated water
Routine cleaning	ease of routine cleaning	all products are within an acceptable range
Routine maintenance/ cleaning interval	time between necessary maintenance or cleaning	Indian consumers already tend to clean more than necessary
Status indicator	communicates proper functioning	while desirable, difficult and costly to implement
Treated water appearance		all products are within an acceptable range
Treated water odor		all products are within an acceptable range
Treated water taste		all products are within an acceptable range
Treated water temperature		all products are within an acceptable range
Treated water volume	storage capacity of treated water (L)	consumers adapt to a broad range of volumes
Turbidity reduction	improvement in the clarity of the water	all products are within an acceptable range
User assistance	effectiveness of any documentation	design the product to avoid a manual altogether (e.g., assembles only one way)

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